MASTER OF SCIENCE
IN
OPERATIONS RESEARCH

FUNDING SITE CLEANUP AT CLOSING ARMY INSTALLATIONS:
A STOCHASTIC OPTIMIZATION APPROACH

Sureyya Ardic-First Lieutenant, Turkish Army
B.S., United States Military Academy, 1996
Master of Science in Operations Research-December 2001
Advisor: Robert F. Dell, Department of Operations Research
Second Reader: Javier Salmeron, Department of Operations Research

To reduce domestic military infrastructure, the United States enacted two laws that instituted rounds of base realignment and closure (BRAC) in 1988, 1991, 1993, and 1995. As a result of these BRAC rounds, the United States Army has closed or realigned 139 installations. Environmental cleanup is almost $2.3 billion (43%) of the entire cost through 2001 associated with the closure and realignment of these 139 Army installations. The United States Army Base Realignment and Closure Office (BRACO) uses an integer linear program called BAEC (Budget Allocation for Environmental Cleanup) to help determine how to allocate limited yearly funding to installations for environmental cleanup. Considering environmental policies and yearly installation funding requests from 2002 to 2015, this thesis modifies BAEC to better account for uncertainty in future environmental cleanup cost. Based on historic data that show most environmental cleanup cost estimates increase over time, the stochastic BAEC model recommends funding fewer sites than the deterministic BAEC model recommends. The stochastic BAEC model thereby provides funding recommendations with a better chance of staying within limited available yearly funding.

KEYWORDS: Integer Linear Programming, Stochastic Optimization, Environmental Cleanup, Budget Allocation

A LAGRANGIAN HEURISTIC FOR SOLVING A NETWORK INTERDICTION PROBLEM

Levent Bingol-Lieutenant Junior Grade, Turkish Navy
B.S., Turkish Naval Academy, 1996
Master of Science in Operations Research-December 2001
Advisor: Kevin R. Wood, Department of Operations Research
Second Reader: Kelly J. Cormican, Department of Operations Research

This thesis is concerned with solving or approximately solving a maximum-flow network-interdiction problem denoted MXFI: A network user strives to maximize flow of a commodity through a capacitated network, while an interdictor, with limited assets, attempts to destroy links in the network to minimize that maximum flow.

MXFI can be converted to a binary integer program and solved but this approach can be computationally expensive. Earlier work by Derbes (1997) on a Lagrangian-relaxation technique has shown promise for solving the problem more quickly (Derbes, 1997). His technique is extended and algorithms implemented in C to solve MXFI for all integer values of total interdiction resource available, R, in some specified range; interdictable arcs require one unit of resource to destroy. The basic procedure solves MXFI exactly for most values of R, but “problematic values” of R do arise. For one set of test problems, a heuristic handles these values successfully, with optimality gaps that are typically less than three percent.

The algorithms and implementations are tested using five test networks which range in size from 27 nodes and 86 arcs to 402 nodes and 1826 arcs. Using a 700 MHz Pentium III personal computer, the largest problem is solved in 16 seconds.

KEYWORDS: Network Interdiction, Mathematical Modeling, Lagrangian Relaxation.

PREDICTING BATTLE OUTCOMES WITH CLASSIFICATION TREES

Muzaffer Coban-First Lieutenant, Turkish Army
B.S., Turkish Military Academy, 1996
Master of Science in Operations Research-December 2001
Advisor: Thomas W. Lucas, Department of Operations Research
Second Reader: Samuel E. Buttrey, Department of Operations Research

Historical combat data analysis is a way of understanding the factors affecting battle outcomes. Current studies mostly prefer simulations that are based on mathematical abstractions of battles. However, these abstractions emphasize objective variables, such as force ratio. Models have very limited abilities of modeling important intangible factors like morale, leadership, and luck. Historical combat analysis provides a way to understand battles with the data taken from the actual battlefield. The models built by using classification trees reveal that the objective variables alone cannot explain the outcome of battles. Relative factors, such as leadership, have deep impacts on success. This result suggests that combat simulations will have a difficult time predicting combat outcomes unless we can better account for these intangible factors. Historical combat analysis helps us comprehend these factors. The classification model predictions on test sets reveal correct classification rates as high as 79 percent. Considering the variability in the data set this outcome is satisfying. Classification models also reveal that the factors affecting outcome of battles have changed throughout history. The leadership advantage played an important role for hundreds of years. However, in the 20th century, air sorties, tanks, and intelligence showed a higher importance.

KEYWORDS: Predicting Battle Outcomes, Historical Combat Data, Caa, What Relates to Winning, Classification and Regression Trees, Important Factors in Battles, Combat Modeling, Modeling and Simulation

SCHEDULING AND DISTRIBUTING INTRA-THEATER WARTIME POL REQUIREMENTS UNDER UNCERTAINTY

David L. Devlin-Lieutenant Commander, United States Navy
B.S., The Pennsylvania State University, 1991
Master of Science in Operations Research-December 2001
Advisor: Robert F. Dell, Department of Operations Research
Second Reader: Javier Salmeron, Department of Operations Research

The Commander-in-Chief, U.S. Pacific Command (USCINCPAC) Joint Petroleum Office (JPO) oversees the distribution and storage of all petroleum products throughout the Pacific Theater. JPO planners have available a series of optimization models to help determine if intra-theater wartime petroleum requirements can be satisfied for a given operational scenario based on known infrastructure capabilities. Although these models provide valuable insight, none directly address the potential for enemy disruption at an uncertain time and/or place. This thesis develops optimization models that account for this kind of uncertainty to assist JPO establish and alter delivery schedules for fuel entering a fuel network as well as movement within the network. It demonstrates these optimization models using a notional 120 day data set for Japan. When compared to the traditional spreadsheet approach, these models demonstrate the same level of performance can be achieved with approximately 25% less deliveries. Eighteen separate attack scenarios suggested by USCINCPAC on network infrastructure then assess the ability of the network to withstand enemy disruption to critical fuel infrastructure and recommend how to best hedge against such attacks. In addition, a scenario simulating a biological attack to a port facility that causes substantial degradation to

network performance demonstrates the robust ability of a reactionary model to re-optimize and alter the existing delivery schedule to minimize shortfalls.

KEYWORDS: Fuel, Petroleum, Distribution, Transportation, Logistics, Linear Programming, Optimization, Operational Planning

OPERATIONAL LOGISTICS WARGAME

Carolyn S. Fricke-Lieutenant Commander, United States Navy
B.S., University of Southwestern Louisiana, 1985
Master of Science in Operations Research-December 2001
Advisor: Arnold Buss, Department of Operations Research
Second Reader: CDR Kevin J. Maher, USN, Department of Operations Research

This thesis provides an interactive wargame for use by students of Operational Logistics at the Naval Postgraduate School. The objective of the wargame is to show students how their decisions regarding resupply of combatant forces affect the ability of those forces to carry-out their wartime missions. The core programming of the Operational Logistics Wargame, as presented by this thesis, deals with a Carrier Battle Group and its missions of command of the sea and power projection ashore. Written in a modular fashion, the wargame can be expanded in scope at a later date to include other combatant missions and components such as submarines, amphibious forces, or ground forces. The modular design allows the wargame to have modifications made to it without alterations to components not directly involved. The wargame also draws data from an outside database by using Structured Query Language (SQL) and a Java Database Connectivity - Open Database Connectivity (JDBC-ODBC) Bridge. The wargame can be installed on most major operation systems. Other major design features of the wargame are Discrete Event Simulation and extensive use of Graphical User Interfaces (GUIs) for providing information to the user and obtaining information from the user.

KEYWORDS: Operational Logistics, Operations Research, Discrete Event Simulation, Wargame, Simulation, JDBC, JDBC-ODBC, GUI, Graphical User Interface, Java Swing, Java

OPTIMIZED PROCUREMENT AND RETIREMENT PLANNING OF NAVY SHIPS AND AIRCRAFT

Ruben M. Garcia-Lieutenant Commander, United States Navy
B.S., United States Naval Academy, 1988
Master of Science in Operations Research-December 2001
Advisors: Robert F. Dell, Department of Operations Research
Javier Salmeron, Department of Operations Research
Second Reader: Gerald G. Brown, Department of Operations Research

The Capital Investment Planning Aid with Air Planning Update (CIPA APU) is a force structure planning tool that can be used to suggest ship, submarine, and aircraft procurement and retirement schedules over a 30-year horizon. These plans represent over a $1 trillion commitment to ensure the Navy stays capable to fulfill its missions. Navy long-range force structure planners at the Chief of Naval Operations, Assessment Division (N81), currently manually prepare alternate future ship, submarine, and aircraft procurement and retirement schedules and evaluate these with a contractor-developed spreadsheet tool. This tool, the Extended Planning Annex/Total Obligated Authority (EPA/TOA) model, estimates the financial impact of any complete future plan over a 30-year horizon. While manually preparing such plans, N81 Force Structure Planners must consider annual budget, industrial base, and force structure requirements expressed in terms of the number of platforms needed to support a mission. With yearly time fidelity, CIPA APU replaces manual planning with optimized budget planning, with, for example, 19 mission areas, 19 ship classes, 58 aircraft types, five ship-production facilities, and three categories of money. CIPA APU tracks average aircraft age, expected attrition, and allows planners to specify a platform's mission suitability. It also provides expeditious feedback to requests for alternate scenario feasibility and budget impact. CIPA APU capabilities are demonstrated using a few realistic scenarios.

KEYWORDS: Operations Research, Integer Programming, Procurement, Capital Investments, Military Capital Budgeting, Optimization, Average Aircraft Age, Aircraft Effectiveness, Aircraft Attrition

OPTIMAL STATIONING OF US ARMY FORCES IN KOREA

Muzaffer Gezer-First Lieutenant, Turkish Army
B.S., Turkish Military Academy, 1996
Master of Science in Operations Research-December 2001
Advisor: Robert F. Dell, Department of Operations Research
Second Reader: Javier Salmeron, Department of Operations Research

Closing and realigning installations has long been a part of the United States (US) Army's reformation. Since 1988, more than 100 Army bases have been closed and 20 others significantly realigned within the U.S. Since the end of the Cold War, the U.S. Army has closed seven of every ten bases in Europe. These extensive overseas closures do not receive the same level of U.S. public attention as those taking place within the U.S. but they represent the fundamental shift from a forward-deployed force to one relying upon overseas presence and power projection. To develop closure and realignment recommendations for installations located in the U.S., the Army has developed the integer linear program OSAF (Optimal Stationing of Army Forces). This thesis modifies OSAF to study the stationing of U.S. units and closure of U.S. installations in South Korea. The modified model is called OSAFK (Optimal stationing of U.S. Army Forces in Korea). OSAFK examines multiple stationing alternatives simultaneously and provides an optimal (minimum cost) stationing for a given set of units and installations while observing budgetary restrictions and stationing policy. OSAFK is demonstrated using a limited data set that considers 51 installations and 194 units. The 20-year net present value of the total cost and the stationing recommended by OSAFK is compared under various levels of budget and find the potential for a substantial reduction to the 20-year net present value.

KEYWORDS: Base Realignment and Closure, BRAC, Integer Linear Programming, Efficient Facility Initiative, EFI, Army Stationing, Facility Location Problem